

THE EFFECTS OF VARYING INTENSITY
ON THE AUDITORY TIME-ERROR

By
JOHN ANTHONY BOWLAND

A DISSERTATION PRESENTED TO THE GRADUATE COUNCIL OF
THE UNIVERSITY OF FLORIDA
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE
DEGREE OF DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA
June, 1958

ACKNOWLEDGMENTS

The author is grateful for the assistance of the members of his committee: Dr. James C. Dixon, chairman; Dr. Elmer D. Hinckley; Dr. E. Porter Horne; Dr. Rolland H. Waters; and Dr. George R. Bartlett. Special mention must be made of the late Dr. Henry Wunderlich whose inspiration and constructive criticism are genuinely appreciated. Acknowledgment is also made of the assistance of Mr. Mack Emmerman of Hi-Fi Associates, Mr. Jack Benson of the University of Miami Speech Clinic, and Dr. Robert Tallarico of the University of Miami Psychology Department.

TABLE OF CONTENTS

	Page
ACKNOWLEDGMENTS	ii
LIST OF TABLES	iv
Chapter	
I. INTRODUCTION	1
II. EXPERIMENTAL DESIGN	14
III. RESULTS AND INTERPRETATION	23
IV. SUMMARY AND CONCLUSION	44
LIST OF REFERENCES	49

LIST OF TABLES

Table		Page
1.	Intensity Values in Decibels of the Stimuli in the 60 Tone Combinations	16
2.	Intensity Values in Decibels of the Stimuli of Discrimination Tests A and B	17
3.	Number of "Louder" Responses for Each of 60 Tone Combinations per 3 Trials and Total.	24
4.	Sign Tests of Inter-Trial Differences: 3 Trials Compared with Each Other per 60 Tone Combinations. . .	26
5.	Summary of "Louder" Responses per Cell: Total Number, Mean per Subject, Variance, Percentage, and D Percentage	29
6.	Tests of Homogeneity of Variance: F-Ratios of Cell Variances to Each Other.	30
7.	Gil Square Tests of the Normality of Cell Distributions	32
8.	Sign Tests of Inter-Cell Differences	34
9.	Analysis of Variance, Single Variable of Classification, for Cell Differences as a Function of Standard and Interpolated Stimulus Intensity Differential Hypothesis III	36
10.	Number of Correct Responses per Tone Combination of Discrimination Tests A and B	39
11.	Complex Analysis of Variance for Subject Differences .	41

CHAPTER I

INTRODUCTION

The various forms of comparison are fundamental to experimental psychology. All experimental procedures for comparison involve the presentation for judgment of at least two objects, stimuli, or sensations which may be separate either in space or time. The subject reports whether the second is lighter, louder, brighter, etc., than the first. In the early comparison experiments the following phenomenon was observed: a second stimulus, equal in value to the first, was over- or under-estimated. When the stimuli are separate in time, such an error is designated a "time-error" (TE). Time-errors and series effects, misjudgments of stimuli on the basis of their position in a series of presentations, constitute the major constant errors in psychophysics.

The present study is concerned with the auditory time-error. Judgments are made comparing the relative loudness of pairs of tones, both with and without an interpolated middle tone. The intensity of the tones is systematically varied in order to measure the effect on time-error. Inter-trial effects and individual differences are evaluated. Beyond generating a broad range of new data, the experiment is designed to test several time-error hypotheses. The latter include Lauenstein's

"assimilation" hypothesis, Pratt's "sinking-trace" hypothesis, and a number of predictions derived from a revised assimilation concept.

Definition of Terms

Before proceeding to a historical development of time-error theories and a review of the literature, some terminology requires clarification. The stimuli in time-error experiments are given the following designations: the first is the "standard stimulus" (St); the middle term, when there is one, is the "interpolated stimulus" (In); and the last is the "comparison stimulus" (Co). Judgments are always made of the comparison stimulus in relation to the standard stimulus. Time errors are either positive or negative: a "positive time-error" (+TE) refers to an underestimation of the comparison stimulus, while a "negative time-error" (-TE) refers to an overestimation of it.

Related Literature

According to Needham (5), in his review of time-error studies, the first systematic observation of the time-error with lifted weights was made by Fechner in 1869 who noted a persistent tendency for subjects to overestimate the Co weight. Fechner attempted to compensate for this negative time-error by presenting each weight in both positions, supposing that he was introducing two asymmetries which would cancel each other's effects. In a theoretical consideration of the phenomenon, Fechner developed a "memory image" theory. Successive

presentation was said to involve the comparison of a current sensation with the image of an earlier sensation. The "fading" or "sinking" of the image decreased the effective comparison value of the first sensation. Since an image was supposed to fade progressively in time, the memory image theory was thought to be supported by experimental evidence that the negative time-error increased as a function of the time interval. Fechner's conception prevailed for several decades. Supporting evidence was gathered in experiments with weights, tones, and brightnesses.

Needham (5) notes further that failures to gain introspective evidence of a mediating image led A. Lehmann in 1891 to restate the theory in terms of an unconscious image operative in some modalities. With Fechner's memory image theory in disrepute, Needham says that two new attempts were made to account for the facts of time-error. One was by G. E. Mueller and L. J. Martin in 1899 who reported that Fechner's "correction" for time-error was inadequate. They isolated statistically three factors which were assumed to account for time-errors found in judging weights: muscular set, mental set, and fatigue. Their three factor theory was implausible when applied to other modalities--e. g., muscular set does not seem relevant to audition. Another attempt was made by Lehmann in 1906 to account for the facts in physiological terms. The standard stimulus was assumed to set up an excitation which persisted in time. The residual of this St excitation then either "inhibits" or "facilitates" the second (Co) excitation when it is induced.

If the second excitation is inhibited, the Co is underestimated and a positive time-error occurs; but if it is facilitated, the Co is overestimated and a negative time-error occurs. He devised a mathematical formula to express the dependence of this "facilitation-inhibition process" upon the length of the time interval, a relationship now called the "p-function," but interest in the problem waned.

Interest in the time-error was revived by Koehler's (3) publication in 1923 of auditory time-error data with a Gestalt interpretation. With the shorter time intervals (0-3 sec.) a +TE was obtained, but with the longer intervals (3-12 sec.) the TE was increasingly negative.

Koehler introduced a trace theory to account for the dependence of the time-errors on the length of the time intervals. The subjective experiences of the St and Co were regarded as correlates of electrochemical events in the cortex. With the cessation of the St, the excitation undergoes a short ionic build-up and then gradually wanes during a period of ionic dissimulation. A Co of equal value is underestimated after a short interval when the St trace is strong, but overestimated after longer intervals when the St trace is waning. Thus the comparison judgment depends on the differential strength of the Co excitation and the St trace, which are assumed to be located in adjacent cortical areas.

Lauenstein (4) expanded the Gestalt interpretation of time-error to include comparative judgments made under conditions of inter-

polated stimulation. He posed two alternative explanations of time-error: either the St trace decreases in intensity due to metabolic decomposition or it becomes assimilated to the level of excitation of the following interval, which he believed to have a "zero stimulus value." (Parenthetically, it should be noted that the empty interval between the St and Co can only approach a zero level of excitation, either physically or phenomenally.)

Lauenstein tested the assimilation hypothesis by varying the excitation level of the intervals for auditory and visual stimuli. Using moderately intense St and Co, he presented either weak or strong In. It was predicted that a St trace would be weakened by assimilation to a weak In, resulting in a -TE; but strengthened by assimilation to a strong In, resulting in A + TE. With short intervals he obtained a slight -TE, but as the intervals were lengthened the TE increased: -TE with weak In, +TE with strong In.

Pratt (9) doubted the validity of Lauenstein's assimilation hypothesis. He tested it with intensity comparisons of sounds. His three series had matched St and Co, and in two of the series another stimulus, either louder or softer, was interpolated. Underestimation of the Co was found in the series with loud In and overestimation in the series with soft In. The degree of overestimation (-TE) was greater for the soft In series than for the series with no In. On finding this relationship to hold for weights also, Pratt concluded that the assimilation hypothesis does not hold when there is no In,

in which case "...the trace merely sinks." Pratt formulated a two factor (assimilation and sinking) theory of trace. "Trace" was used as an empirical, rather than a physiological construct. The two factors were related to retroaction in learning theory. Further experimentation (10) led him to incorporate the notion that general levels of reference built up through prior experience influence present judgments.

In the year of Lauenstein's publication, 1933, Woodrow (12) began formulating a purely psychological explanation of time-error data. He rejected "trace" with its physiological implications, substituting "set"—a readiness for a stimulus of a certain character.

The following assumptions were made:

1. In intensity comparisons there exists a set toward a certain intensity level.
2. "The level of the set tends to approximate the average intensity of the entire series..."
3. The more recent stimuli have greater influence in determining the average intensity of the series.
4. "The level of intensity toward which S is set tends in all cases to sink toward a lower level (*ceteris paribus*), but does not even remotely approach a level of zero as long as the set is maintained."

Woodrow suggested that another level might be involved, an "absolute indifference set" based on the individual's whole history of intensity experiences or innate constitutional difference.

These assumptions were used by Woodrow (13) to explain further results obtained from judgments of temporal intervals. An extrapolation from intensity to duration was made by analogously equating long

with loud and short with soft. At the beginning of experimentation only the absolute or lower indifference level is operative, and this level is short enough to produce a negative time-order error. But as the central tendency becomes established, the time-order error tends to be negative for the longer (1.2 secs.) stimuli and positive for the shorter (.8 secs.) stimuli, although negative errors are slightly the more frequent since the absolute set is still operative. Woodrow's later work continued to explore the perception of time and his set theory has not been tested in its original intensity time-error setting.

In 1934, Needham (6) studied the effects of practice on the time-error of auditory intensity. Six subjects repeatedly made judgments during a nine-day period, with intervals between St and Co of 1, 2, 4, and 8 seconds. His findings confirmed Koehler's results, so far as the latter went, that the time-error diminished with practice, losing its linear decline with increased intervals as a function of continued experimentation. Further, he found the time-error curve reversed by the ninth day. The individual differences in practice effects were striking, even though the subjects were sophisticated.

Koehler's determination of the p-function, the dependence of the time-error on the length of the interval, for auditory intensity was also confirmed in an extensive experiment by Postman (8) in 1946.

Basic research on the auditory time-error, oriented toward theoretical questions, virtually stopped in 1946. The studies most directly concerned with interpolated stimuli and the assimilation

hypothesis are inadequate in design: few subjects, protracted sessions, use of number of judgments rather than number of subjects for N, and critical ratios between distributions of doubtful normality. The gross individual differences found by Needham and the striking practice effects obtained by both Needham and Koehler cast considerable doubt on Pratt's results. He used three subjects for protracted experimentation. In addition, there are difficulties in accurate timing with a manually operated sound pendulum, and an inequity in comparing a 4 sec. empty interval with a 4 sec. interval containing a fraction of a second In. (In contrast, Lauenstein conceptualized in figure-ground relationships, the In beginning with the termination of the St and stopping at the onset of the Co.) Another study by Needham (7) showed that a brief In loses its effectiveness as a function of lengthened intervals.

The more recent developments in the time-error field are largely concerned with the following: visual forms, where the stimulus configurations are too complex to answer the questions posed in the earlier studies; judgments of temporal intervals; time-error and cortical lesions (11); and statistical manipulation of the older questionable data and data from more complex judgments to formulate mathematical expressions of Helson's "adaptation level" (1). These developments have proceeded without a fair test of the set theory or the Gestalt theory, both of which have broad applicability in the fields of learning and perception. Pratt's interpretation of his results concerning assimilation and sinking-trace is accorded a surprising degree of acceptance.

Woodworth and Schlosberg (14, p. 229), for example, make the following conclusion: "Assimilation does not account for the ordinary TE with a vacant interval. Assimilation belongs with the series effects..."

Lauenstein's term "assimilation" is useful in that it denotes an interaction or merging of St and In values. In this general sense assimilation is commonly accepted as helpful in accounting for time-errors resulting from interpolated stimulation and central tendency or series effects. But Lauenstein's specific formulation of assimilation, particularly in the case of the empty interval, and Pratt's subsequent refutation of it have led to a two factor theory of the major constant errors in psychophysics. A revision of the assimilation concept may make it possible to order these effects under one theory. Lauenstein believed that the St trace was assimilated to the In excitation. This does not appear to follow from general Gestalt principles. It limits the interaction to one trace and one excitation and does not take into account the whole gradient system.

The revised assimilation concept is formulated in terms of a psychophysical parallelism. The phenomenal experience of comparison (e. g. "louder") is the psychological parallel of a physical excitation being assimilated to the traces of past excitations. The term "trace" refers to a cortical residual of the neural excitation caused by a stimulus. The traces are assumed to be organized in relatively persistent subsystems which interact with one another and the whole gradient system. The current excitation, whether St, In, or Co, is

assimilated to or merged with the subsystem, the differential value of the excitation and subsystem paralleling the experience of comparison. On being assimilated, the newly formed trace is assumed to contribute more heavily to the mean value of the subsystem since it is a current excitation, either raising or lowering the mean value, rather than simply adding to the total value of the subsystem. The value of a subsystem may be defined operationally as its effective comparison value.

A current excitation is assimilated to a subsystem of a similar character, e. g., the same sense modality and attribute. Tonal excitations varying in intensity are presumably assimilated to a subsystem of tonal intensity traces. However, tonal intensity may be affected by pitch and even illumination through interaction of subsystems, depending on their cohesiveness and insulation. Again, the degree of interaction may be determined experimentally, by measuring the effects of varying pitch or illumination on tonal intensity comparisons, for example. The general Gestalt principles of figure-ground system formation, contrast, proximity, symmetry, articulation, etc., are assumed to function. While the viewpoint is associated with an electro-chemical, rather than a structural, theory of cortical action, the view need not be dependent on any such theory.

Several propositions of the revised assimilation view need special emphasis in relation to the empirical predictions of the present study. Under conditions of varying only tonal intensity, only one

subsystem is assumed to be affected. Each incoming excitation is assimilated to that subsystem. The incoming excitation contributes inordinately to the mean level of intensity of the subsystem: a loud stimulus raising it, a soft stimulus lowering it. Thus, with In controlled, the effective comparison value of a St will be displaced toward a moderate value, with consequent underestimation of soft Co's and overestimation of loud Co's. Further, since a recent stimulus contributes more heavily to the mean value of the subsystem, it is partly the relation of the In intensity to that of its preceding St which determines the Co estimation. The greater the In in relation to its St, the greater the displacement upwards of the subsystem's effective comparison value, and the greater the underestimation of the Co.

Lauenstein's assimilation hypothesis requires that, because an St is assimilated toward an In's level, a "zero" In leads to greater overestimation of the Co than does a soft In. Pratt's sinking-trace concept requires that in the absence of an In the trace of the St sinks or decreases in effective comparison value, leading to overestimation of the Co. A fair test of the sinking-trace effect may be made by introducing a control In (besides other design improvements), and requiring the effective comparison value of the St to decrease more when followed by an empty interval than when followed by an In of equal value (to the St). In contrast to the formulations of Lauenstein, Pratt, and Woodrow, in the revised assimilation view the effective comparison value of the St (actually, the subsystem) is assumed to be relatively persist-

ent. In the absence of an In there should be no more displacement of the subsystem's effective comparison value than if the St were followed by an In of the same value.

A subsystem which is poorly articulated, for whatever reasons, may not be expected to show the above specified characteristics as clearly or reliably. That is, under a given procedure of experimental stimulation the above specified revised assimilation effects may gradually develop, progress, or increase.

The present experiment was designed to test predictions derived from Pratt's sinking-trace concept, Lauenstein's assimilation hypothesis, and the revised assimilation view. A broad range of data is generated under experimental conditions which take into account practice and fatigue effects and subject differences. In comparison with previous interpolated time-error studies, more levels of intensity are employed and the stimulus presentation is more adequate. Time-error differences are evaluated as follows: inter-trial differences; the effects of varying the intensity level of standard stimuli, with interpolated stimuli controlled; and the effects of varying interpolated stimuli, with standard stimuli controlled.

The subjects make judgments of "louder" or "softer" to 60 tone combinations of different intensities: 3 St x 4 In x 5 Co. The 60 combinations are replicated in three successive trials, 180 judgments per subject, under the Method of Constant Stimuli.

Hypotheses

Hypothesis I: If reliable inter-trial differences occur, they will be in the direction of inter-trial increments or progressions in the effects defined in Hypotheses II, III, and VI.

Hypothesis II: With In controlled, a soft St will lead to overestimation of the Co, a loud St will lead to underestimation of the Co, and a moderate St will have an intermediate effect.

Hypothesis III: Exclusive of the zero In or empty interval, the greater the In intensity in relation to the intensity of the St, the greater the underestimation of the Co.

Hypotheses IV, V, and VI are sets of predictions derived from the assimilation, sinking-trace, and revised assimilation concepts, respectively, concerning the zero In or empty interval. Each hypothesis is tested at three levels of St intensity: soft, moderate, and loud.

Hypothesis IV: A Co will be overestimated more when the St is followed by a zero In than when followed by a soft In.

Hypothesis V: A Co will be overestimated more when the St is followed by a zero In than when followed by an equal In.

Hypothesis VI: A Co will be no more over- or under-estimated when the St is followed by a zero In than when followed by an equal In.

CHAPTER II

EXPERIMENTAL DESIGN

Subjects

The subjects were 26 volunteer male students in two introductory psychology courses at the University of Miami. Their mean age was 20.7 years. None had any significant hearing loss in lower threshold. This was defined a priori as ability to perceive a tone of 20 decibels (db.) in either ear, in both ascending and descending series of 500, 1000, and 1500 cycles per second (c.p.s.). Four potential subjects were excluded for failing to meet these standards.

Stimuli

The stimuli were presented by means of a tape recorder. They were arranged in combinations of three tones: St-In-Co. The subject reported whether the last (Co) was "louder" or "softer" than the first (St). The frequency of all tones was 1000 c.p.s. Three levels of intensity of St were used: soft (S)—45 db., moderate (M)—57.5 db., and loud (L)—70 db. There were four levels of intensity in In: none (0)—"0 db.", soft (S)—45 db., moderate (M)—57.5 db., and loud (L)—70 db. For each St there were five Co, 2.5 db. apart, symmetrical to the St, i. e., the central Co coincides in intensity with that of the St.

This is a form of the Method of Constant Stimuli. All 12 possible combinations of St and In were used, each combination with all 5 Co appropriate to the St. These 60 combinations ($3 \text{ St} \times 4 \text{ In} \times 5 \text{ Co}$) were presented in random order to each subject three times, Trial 1, Trial 2, and Trial 3, which differ only in their order in the experiment. Thus each subject made 180 judgments. The 60 combinations are shown in Table 1.

The timing of combinations was as follows: St—1 sec., pause—.5 sec., In—2 sec., pause—.5 sec., Co—1 sec. Each combination was followed by a 6 sec. rest interval, during which time the subject reported his judgment.

Two additional tapes were presented to test the relative difficulty of discrimination at the different intensity levels. Discrimination Test A consisted of 14 St-Co pairs differing by 2.5 db. Discrimination Test B consisted of 13 St-Co pairs differing by 5 db. In these two tests each St and Co was presented for 1 sec., each pair of stimuli separated by a .5 sec. interval. Each combination was followed by a 4 sec. rest period, during which time the subject reported his judgments under the same instructions as before. The St-Co combinations and their order for Discrimination Tests A and B are shown in Table 2.

In addition to furnishing a rough measure of the relative difficulty of discriminations at different levels of intensity, these tests are of interest for technical reasons. While no hypotheses are

TABLE 1

INTENSITY VALUES IN DECIBELS OF THE STIMULI IN
THE 60 TONE COMBINATIONS

Cell Label	Db.			Cell Label	Db.		
	<u>St</u>	<u>In</u>	<u>Co</u>		<u>St</u>	<u>In</u>	<u>Co</u>
<u>S-O</u>	45.0	0.0	50.0	<u>M-M</u>	57.5	57.5	62.5
	45.0	0.0	47.5		57.5	57.5	60.0
	45.0	0.0	45.0		57.5	57.5	57.5
	45.0	0.0	42.5		57.5	57.5	55.0
	45.0	0.0	40.0		57.5	57.5	52.5
<u>S-S</u>	45.0	45.0	50.0	<u>M-L</u>	57.5	70.0	62.5
	45.0	45.0	47.5		57.5	70.0	60.0
	45.0	45.0	45.0		57.5	70.0	57.5
	45.0	45.0	42.5		57.5	70.0	55.0
	45.0	45.0	40.0		57.5	70.0	52.5
<u>S-M</u>	45.0	57.5	50.0	<u>L-O</u>	70.0	0.0	75.0
	45.0	57.5	47.5		70.0	0.0	72.5
	45.0	57.5	45.0		70.0	0.0	70.0
	45.0	57.5	42.5		70.0	0.0	67.5
	45.0	57.5	40.0		70.0	0.0	65.0
<u>S-L</u>	45.0	70.0	50.0	<u>L-S</u>	70.0	45.0	75.0
	45.0	70.0	47.5		70.0	45.0	72.5
	45.0	70.0	45.0		70.0	45.0	70.0
	45.0	70.0	42.5		70.0	45.0	67.5
	45.0	70.0	40.0		70.0	45.0	65.0
<u>M-O</u>	57.5	0.0	62.5	<u>L-M</u>	70.0	57.5	75.0
	57.5	0.0	60.0		70.0	57.5	72.5
	57.5	0.0	57.5		70.0	57.5	70.0
	57.5	0.0	55.0		70.0	57.5	67.5
	57.5	0.0	52.5		70.0	57.5	65.0
<u>M-S</u>	57.5	45.0	62.5	<u>L-L</u>	70.0	70.0	75.0
	57.5	45.0	60.0		70.0	70.0	72.5
	57.5	45.0	57.5		70.0	70.0	70.0
	57.5	45.0	55.0		70.0	70.0	67.5
	57.5	45.0	52.5		70.0	70.0	65.0

TABLE 2
INTENSITY VALUES IN DECIBELS OF THE STIMULI OF
DISCRIMINATION TESTS A AND B

Test A		Test B	
Db.		Db.	
St.	Co	St	Co
42.5	40.0	45.0	40.0
42.5	45.0	42.5	47.5
47.5	45.0	50.0	45.0
47.5	50.0	52.5	47.5
52.5	50.0	50.0	55.0
52.5	55.0	52.5	57.5
57.5	55.0	60.0	55.0
57.5	60.0	62.5	57.5
62.5	60.0	60.0	65.0
62.5	65.0	62.5	67.5
67.5	65.0	70.0	65.0
67.5	70.0	72.5	67.5
72.5	70.0	70.0	75.0
72.5	75.0		

based on the assumption that the intensity values of S and L are phenomenally equidistant from M, such a condition is assumed to be approached under the conditions of this experiment. This assumption would not be tenable under a fractionation procedure. But in the present case it is tenable because the decibel scale values employed are not extreme but fall within a range wherein the decibel scale and the summated difference limen scale are very similar in slope. Both discrimination tests involve stimuli distributed throughout the range and thus would reflect any gross asymmetries. These "tests" are also subject to time-errors of course.

Apparatus

A new Wilcox-Gay model 5-U tape recorder was obtained especially for the purpose of the experiment and used throughout, both in recording and presenting the stimuli. Its qualifications are as follows: four speakers--two five inches by seven inches and two electrostatic tweeters; frequency response of 65 to 15,000 cycles; signal to noise--35 db. minimum; wow and flutter--20 at 7.5 inches per second (i.p.s.).

Several minutes of each decibel level were recorded on 15 separate tapes. These recordings were made at a speed of 7.5 i.p.s. by direct connection to a Maico model H-1 audiometer in a sound-proof room. The tapes were then cut into the required lengths and spliced together in the 60 different combinations.

The subjects used Telux "Tele-Fi" binaural earphones, weighing one-half ounce (less cord), fitted in the ears by foam plastic tips.

The experimenter also listened to all the tones, but only monaurally.

Procedure

All experimentation took place in the University of Miami Speech Clinic. After a few minutes of conversation, the subject was told that the experimental purpose was to develop a tape recorded hearing test. The audiometric screening test was then administered in a small "sound-proof" room. This took about ten minutes. The subject was then seated opposite the experimenter at a table in a large, quiet office. On the table stood the tape recorder, from which two pairs of earphones extended. The form on which the subject's responses were recorded was behind the tape recorder, out of his sight. The subject was then told that the (remainder of the) experiment would take 40 to 45 minutes.

The instructions were as follows: "You will hear series of tones and simply judge whether the last is louder or softer than the first. The tones will differ only in intensity, not in pitch. Each series will usually consist of three tones--first, middle, and last--but sometimes the middle tone will be omitted. It will be easy to tell if there will be a middle tone because it quickly follows the first. Say "louder" or "softer" depending on whether you think the last is louder or softer than the first." The instructions were then paraphrased to make clear three points: that intensity, not pitch was the variable; that the time between the first and last tones would be the same whether or not there was a middle tone; and that only "louder" or "softer"

responses were permissible. Three subjects failed to respond to the first combination in which a middle tone was omitted. The instructions were clarified and the combination repeated, with no further confusion. After each subject's response to the first combination, the experimenter asked, "Last one louder (or softer)?"

Three trials each consisting of 60 combinations of tones were presented to the subject. Each trial took 11 minutes and was followed by a three minute rest period, during which time the tape was rewound. Each subject was informally asked about his approach to the judgments and asked if any particular combination of tones seemed easier or more difficult. Before the second and third trials, the subject was simply told that the instructions were the same.

At the end of the third trial, the subject was told that in the remaining few minutes he would be asked to make the same kind of judgments on a number of combinations consisting of only two tones. Discrimination Tests A and B were then administered with a two-minute break between them.

Hypotheses

The hypotheses are cast in terms of the twelve cells (e. g., S-O, S-S) shown in Table 1. These cells represent all possible St-In combinations. Each cell entry will be the mean number of "louder" responses to one St-In combination with five Co's on three trials.

It should be noted that O ("0" db.), S (45 db.), M (57.5 db.),

and L (70 db.) have fixed intensity values. While S-M, M-M, and L-M have the same In (M), its relation to the St in each case is different: louder (45-57.5 db.), equal (57.5-57.5 db.), and softer (70-57.5 db.).

Hypothesis I: If reliable inter-trial differences occur, they will be in the direction of inter-trial increments or progressions in the effects defined in Hypotheses II, III, and VI.

Hypothesis II: With In controlled, a soft St will lead to overestimation of the Co, a loud St will lead to underestimation of the Co, and a moderate St will have an intermediate effect: $\underline{S-S} < \underline{M-M}$; $\underline{S-S} < \underline{L-L}$; $\underline{M-M} < \underline{L-L}$.

Hypothesis III: Exclusive of the zero In or empty interval, the greater the In intensity in relation to the intensity of the St, the greater the underestimation of the Co: $\underline{L-S} > \left[\frac{(\underline{M-S} \quad \underline{L-M})}{2} \right] > \left[\frac{(\underline{S-S} \quad \underline{M-M} \quad \underline{L-L})}{3} \right] > \left[\frac{(\underline{S-M} \quad \underline{M-L})}{2} \right] > \underline{S-L}$. The first term (L-S) represents the St which has an In two steps lower; the second term, 2 St which have In's one step lower; the third term, 3 St's with equivalent In's; the fourth term, 2 St's with In's two steps higher; the last term, the St with an In two steps higher. Each term which incorporates more than one cell entry is divided by the number of cells involved, in order to offer comparisons of mean numbers of "louder" responses between terms.

Hypotheses IV, V, and VI are sets of predictions derived from the assimilation, sinking-trace, and revised assimilation concepts, respectively, concerning the zero In or empty interval. Each hypothesis

is tested at three levels of St intensity: soft, moderate, and loud.

Hypothesis IV: A Co will be overestimated more when the St is followed by a zero In than when followed by a soft In: $\underline{S-O} > \underline{S-S}$; $\underline{M-O} > \underline{M-S}$; $\underline{L-O} > \underline{L-S}$.

Hypothesis V: A Co will be overestimated more when the St is followed by a zero In than when followed by an equal In: $\underline{S-O} > \underline{S-S}$; $\underline{M-O} > \underline{M-M}$; $\underline{L-O} > \underline{L-L}$.

Hypothesis VI: A Co will be no more over- or under-estimated when the St is followed by a zero In than when followed by an equal In: $\underline{S-O} = \underline{S-S}$; $\underline{M-O} = \underline{M-M}$; $\underline{L-O} = \underline{L-L}$.

CHAPTER III

RESULTS AND INTERPRETATION

Table 3 presents the total number of "louder" responses for each of the 60 St-In-Co combinations on each of the three trials.

Hypothesis I—that if there are inter-trial differences, they will be in the direction of progressive assimilation effects—is testable before further summarization of results. A sign test was performed between Trials 1 and 2, 1 and 3 and 2 and 3 for each of the 60 combinations. These sign tests are shown in Table 4. The number of "louder" responses per combination per trial per subject was tabulated. In comparing Trials 1 and 2 on the first combination, for example, a subject could have made more, less, or an equal number of "louder" responses. The proportion of subjects whose judgments changed from trial to trial on a given combination determines the reliability of inter-trial differences. In Table 4, the signs (+, -, and =) refer to the direction of shifts in judgment.

Of the 180 sign tests of inter-trial differences, only one is significant at the .01 level and one at the .05 level. These two differences may be attributed to chance because of the large number of tests involved. Thus inter-trial differences are not accepted as reliable, and the following interpretations are made: (1) no successive

TABLE 3

NUMBER OF "LOUDER" RESPONSES FOR EACH OF 60 TONE COMBINATIONS PER 3 TRIALS AND TOTAL

Cell Label	Db.			Number of "Louder" Responses			
	<u>St</u>	<u>In</u>	<u>Co</u>	Trial			Total
				1	2	3	
<u>S-O</u>	45.0	0.0	50.0	9	10	15	34
	45.0	0.0	47.5	10	10	12	32
	45.0	0.0	45.0	10	2	5	17
	45.0	0.0	42.5	0	0	0	0
	45.0	0.0	40.0	2	0	0	2
				<u>31</u>	<u>22</u>	<u>32</u>	<u>85</u>
<u>S-S</u>	45.0	45.0	50.0	23	21	23	67
	45.0	45.0	47.5	9	8	5	22
	45.0	45.0	45.0	4	6	10	20
	45.0	45.0	42.5	1	0	0	1
	45.0	45.0	40.0	0	0	0	0
				<u>37</u>	<u>35</u>	<u>38</u>	<u>110</u>
<u>S-M</u>	45.0	57.5	50.0	9	9	8	26
	45.0	57.5	47.5	2	1	0	3
	45.0	57.5	45.0	2	3	2	7
	45.0	57.5	42.5	0	0	0	0
	45.0	57.5	40.0	0	1	0	1
				<u>13</u>	<u>14</u>	<u>10</u>	<u>37</u>
<u>S-L</u>	45.0	70.0	50.0	8	12	14	34
	45.0	70.0	47.5	2	3	4	9
	45.0	70.0	45.0	7	11	8	26
	45.0	70.0	42.5	1	4	0	5
	45.0	70.0	40.0	1	2	1	4
				<u>19</u>	<u>32</u>	<u>27</u>	<u>78</u>
<u>M-O</u>	57.5	0.0	62.5	22	23	20	65
	57.5	0.0	60.0	26	25	24	75
	57.5	0.0	57.5	20	14	17	51
	57.5	0.0	55.0	9	7	5	21
	57.5	0.0	52.5	1	1	0	2
				<u>78</u>	<u>70</u>	<u>66</u>	<u>214</u>
<u>M-S</u>	57.5	45.0	62.5	26	26	26	78
	57.5	45.0	60.0	26	26	25	77
	57.5	45.0	57.5	13	8	11	32
	57.5	45.0	55.0	23	21	25	69
	57.5	45.0	52.5	2	4	4	10
				<u>90</u>	<u>85</u>	<u>91</u>	<u>266</u>

TABLE 3—Continued

Cell Label	Db.			Number of "Louder" Responses			
	<u>St</u>	<u>In</u>	<u>Co</u>	Trial			Total
				1	2	3	
<u>M-M</u>	57.5	57.5	62.5	25	25	26	76
	57.5	57.5	60.0	24	21	23	68
	57.5	57.5	57.5	13	17	14	44
	57.5	57.5	55.0	6	9	8	23
	57.5	57.5	52.5	0	2	2	4
				68	74	73	215
<u>M-L</u>	57.5	70.0	62.5	24	24	23	71
	57.5	70.0	60.0	23	21	19	63
	57.5	70.0	57.5	12	17	22	51
	57.5	70.0	55.0	12	17	17	46
	57.5	70.0	52.5	1	0	2	3
				72	79	83	234
<u>L-O</u>	70.0	0.0	75.0	26	25	26	77
	70.0	0.0	72.5	22	20	19	61
	70.0	0.0	70.0	25	21	23	69
	70.0	0.0	67.5	2	5	2	9
	70.0	0.0	65.0	4	3	1	8
				79	74	71	224
<u>L-S</u>	70.0	45.0	75.0	26	26	25	77
	70.0	45.0	72.5	25	26	24	75
	70.0	45.0	70.0	25	23	22	70
	70.0	45.0	67.5	11	6	7	24
	70.0	45.0	65.0	10	8	7	25
				97	89	85	271
<u>L-M</u>	70.0	57.5	75.0	26	25	25	76
	70.0	57.5	72.5	26	23	25	74
	70.0	57.5	70.0	21	25	22	68
	70.0	57.5	67.5	12	7	9	28
	70.0	57.5	65.0	9	7	9	25
				94	87	90	271
<u>L-L</u>	70.0	70.0	75.0	26	26	26	78
	70.0	70.0	72.5	23	23	24	70
	70.0	70.0	70.0	21	18	20	59
	70.0	70.0	67.5	1	4	2	7
	70.0	70.0	65.0	0	1	0	1
				71	72	72	215

TABLE 4

SIGN TESTS OF INTER-TRIAL DIFFERENCES: 3 TRIALS COMPARED
WITH EACH OTHER PER 60 TONE COMBINATIONS

Series No.	Trials 1-2			Trials 1-3			Trials 2-3		
	+	-	=	+	-	=	+	-	=
1	1	1	24	0	1	25	0	1	25
2	1	1	24	1	0	25	1	0	25
3	0	1	25	0	0	26	1	0	25
4	3	2	21	4	1	21	3	1	22
5	0	3	23	1	0	25	4	0	22
6	8	6	12	6	4	16	3	5	18
7	2	0	24	2	0	24	0	0	26
8	4	4	18	4	6	16	2	4	20
9	4	9	13	1	11 ^b	14	2	7	17
10	5	4	17	6	2	18	6	3	17
11	4	2	20	1	2	23	1	5	20
12	8	3	15	7	3	16	3	3	17
13	3	6	17	2	4	20	6	5	15
14	2	6	18	3	9	14	3	5	18
15	5	5	16	5	4	17	5	4	17
16	9 ^a	1	16	8	3	15	0	3	23
17	10	4	12	5	2	19	3	6	17
18	1	0	25	2	0	24	2	1	23
19	0	0	26	0	0	26	0	0	26
20	1	0	25	1	0	25	1	1	24
21	0	1	25	0	0	26	1	0	25
22	6	3	17	4	3	19	3	5	18
23	4	5	17	4	10	12	4	9	13
24	2	3	21	2	2	22	3	2	21
25	0	0	26	1	0	25	0	1	25
26	0	1	25	2	1	23	2	0	24
27	0	0	26	1	0	25	1	0	25
28	4	1	21	2	1	23	1	3	22
29	0	1	25	1	1	24	2	1	23
30	2	2	22	2	1	23	2	1	23
31	3	3	20	6	2	18	5	3	18
32	7	5	14	7	2	17	3	1	22
33	0	0	26	0	0	26	0	0	26
34	5	3	18	7	4	15	5	4	17
35	1	0	25	0	1	25	0	2	24

^a.05 level of probability

^b.01 level of probability

TABLE 4--Continued

Series No.	Trials 1-2			Trials 1-3			Trials 2-3		
	+	-	=	+	-	=	+	-	=
36	1	4	21	2	2	22	5	2	19
37	0	0	26	0	0	26	0	0	26
38	4	8	14	4	5	17	8	5	13
39	0	0	26	0	0	26	0	0	26
40	5	1	20	3	1	22	2	4	20
41	3	5	18	1	7	18	2	6	18
42	4	2	20	2	2	22	1	3	22
43	2	4	20	2	4	20	2	2	22
44	0	0	26	0	0	26	0	0	26
45	3	8	15	1	6	19	4	4	18
46	4	8	14	4	5	17	9	6	11
47	9	4	13	4	1	21	4	6	16
48	1	2	23	5	3	18	6	3	17
49	3	3	20	2	3	21	2	3	21
50	9	4	13	7	5	14	5	8	13
51	2	1	23	2	0	24	1	0	25
52	0	3	23	1	2	23	3	1	22
53	1	0	25	0	0	26	0	1	25
54	1	5	20	2	3	21	4	1	21
55	2	3	21	2	3	21	2	3	21
56	1	0	25	1	0	25	0	0	26
57	0	2	24	0	2	24	2	2	22
58	6	4	16	7	4	15	4	3	19
59	3	1	22	3	0	23	3	2	21
60	3	0	23	1	0	25	1	3	22

stages in emergence of assimilation effects are identified; (2) the experimental procedure was appropriate for precluding significant fatigue effects; (3) no extraneous inter-trial effects intrude to detract from the generality of assimilation phenomena.

Since inter-trial differences may be attributed to chance, the remaining hypotheses are tested in terms of cell (St-In) entries representing the three trials combined, which adds to the entries' reliability. Table 5 summarizes the "louder" responses of all subjects on all trials per St-In cell, as follows: total number, mean number per subject, variance, percentage, and time error in terms of D percentage (percentage of "softer" minus percentage of louder" responses).

In order to select the appropriate statistical procedures for evaluating cell differences, the 12 distributions were tested for homogeneity and normality.

Bartlett's test of homogeneity was made, resulting in a rejection of the hypothesis that the variances are equal: obtained $F = 10.68$; critical F (d.f.--11,∞) = 2.44 at .01 level.

Cochran's test ($F = \text{largest variance over sum of other variances}$) also resulted in a rejection of this hypothesis although the F might be considered borderline. Table 6 shows the F -ratios of each variance to one another.

A normal distribution having the same mean and variance was constructed for each of the 12 distributions and Chi square computed to evaluate normality. Table 7 shows the results of these tests.

TABLE 5

SUMMARY OF "LOUDER" RESPONSES PER CELL^a: TOTAL NUMBER,
MEAN PER SUBJECT, VARIANCE, PERCENTAGE, AND D PERCENTAGE

<u>St-In</u>	Total No.	Mean	Variance	Percentage	D Percentage
<u>S-O</u>	85	3.27	3.89	21.79	+56.42
<u>S-S</u>	110	4.23	3.00	28.21	+43.60
<u>S-M</u>	37	1.42	1.48	9.49	+81.02
<u>S-L</u>	78	3.00	4.62	20.00	+60.00
<u>M-O</u>	214	8.23	2.08	54.87	- 9.74
<u>M-S</u>	266	10.23	1.54	68.21	-36.42
<u>M-M</u>	215	8.27	3.27	55.13	-10.26
<u>M-L</u>	234	9.00	5.62	60.00	-20.00
<u>L-O</u>	224	8.62	2.16	57.44	-14.88
<u>L-S</u>	271	10.42	3.71	69.28	-38.77
<u>L-M</u>	271	10.42	2.78	69.28	-38.77
<u>L-L</u>	215	8.27	1.16	55.13	-10.26

^aThe cells each represent 390 judgments made to the 12
different St-In combinations: 26 subjects times 5 Co times 3 trials.

TABLE 6

TESTS OF HOMOGENEITY OF VARIANCE: F-RATIOS OF CELL^a
VARIANCE TO EACH OTHER

<u>St-In's</u> Compared F- Ratio			<u>St-In's</u> Compared F- Ratio			<u>St-In's</u> Compared F- Ratio		
<u>S-O</u>	<u>S-S</u>	1.30	<u>S-M</u>	<u>M-O</u>	1.47	<u>M-O</u>	<u>L-M</u>	1.33
<u>S-O</u>	<u>S-M</u>	2.63 ^b	<u>S-M</u>	<u>M-S</u>	1.04	<u>M-O</u>	<u>L-L</u>	1.79
<u>S-O</u>	<u>S-L</u>	1.19	<u>S-M</u>	<u>M-M</u>	2.21	<u>M-S</u>	<u>M-M</u>	2.12
<u>S-O</u>	<u>M-O</u>	1.87	<u>S-M</u>	<u>M-L</u>	3.78 ^b	<u>M-S</u>	<u>M-L</u>	3.65 ^b
<u>S-O</u>	<u>M-S</u>	2.53 ^b	<u>S-M</u>	<u>L-O</u>	1.46	<u>M-S</u>	<u>L-O</u>	1.40
<u>S-O</u>	<u>M-M</u>	1.19	<u>S-M</u>	<u>L-S</u>	2.51 ^b	<u>M-S</u>	<u>L-S</u>	2.41 ^b
<u>S-O</u>	<u>M-L</u>	1.44	<u>S-M</u>	<u>L-M</u>	1.88	<u>M-S</u>	<u>L-M</u>	1.81
<u>S-O</u>	<u>L-O</u>	1.80	<u>S-M</u>	<u>L-L</u>	1.28	<u>M-S</u>	<u>L-L</u>	1.33
<u>S-O</u>	<u>L-S</u>	1.05	<u>S-L</u>	<u>M-O</u>	2.22	<u>M-M</u>	<u>M-L</u>	1.38
<u>S-O</u>	<u>L-M</u>	1.40	<u>S-L</u>	<u>M-S</u>	3.00 ^b	<u>M-M</u>	<u>L-O</u>	1.51
<u>S-O</u>	<u>L-L</u>	3.35 ^b	<u>S-L</u>	<u>M-M</u>	1.41	<u>M-M</u>	<u>L-S</u>	1.13
<u>S-S</u>	<u>S-M</u>	2.03	<u>S-L</u>	<u>M-L</u>	1.22	<u>M-M</u>	<u>L-M</u>	1.18
<u>S-S</u>	<u>S-L</u>	1.54	<u>S-L</u>	<u>L-O</u>	2.14	<u>M-M</u>	<u>L-L</u>	2.82 ^b
<u>S-S</u>	<u>M-O</u>	1.44	<u>S-L</u>	<u>L-S</u>	1.25	<u>M-L</u>	<u>L-O</u>	2.60 ^b
<u>S-S</u>	<u>M-S</u>	1.95	<u>S-L</u>	<u>L-M</u>	1.66	<u>M-L</u>	<u>L-S</u>	1.49
<u>S-S</u>	<u>M-M</u>	1.09	<u>S-L</u>	<u>L-L</u>	3.98 ^b	<u>M-L</u>	<u>L-M</u>	2.02
<u>S-S</u>	<u>M-L</u>	1.87	<u>M-O</u>	<u>M-S</u>	1.35	<u>M-L</u>	<u>L-L</u>	4.84 ^b

^aThe cells each represent 390 judgments made to the 12 different St-In combinations: 26 subjects times 5 Co times 3 trials.

^b.05 level of probability

TABLE 6--Continued

St-In's Compared			St-In's Compared			St-In's Compared		
F-Ratio			F-Ratio			F-Ratio		
<u>S-S</u>	<u>L-O</u>	1.39	<u>M-O</u>	<u>M-M</u>	1.57	<u>L-O</u>	<u>L-S</u>	1.72
<u>S-S</u>	<u>L-S</u>	1.25	<u>M-O</u>	<u>M-L</u>	2.70 ^b	<u>L-O</u>	<u>L-M</u>	1.29
<u>S-S</u>	<u>L-M</u>	1.08	<u>M-O</u>	<u>L-O</u>	1.04	<u>L-O</u>	<u>L-L</u>	1.86
<u>S-S</u>	<u>L-L</u>	2.59 ^b	<u>M-O</u>	<u>L-S</u>	1.78	<u>L-S</u>	<u>L-M</u>	1.33
<u>S-M</u>	<u>S-L</u>	3.12 ^b				<u>L-S</u>	<u>L-L</u>	3.20 ^b
						<u>L-M</u>	<u>L-L</u>	2.40 ^b

^b.05 level of probability

TABLE 7

CHI SQUARE TESTS OF THE NORMALITY OF CELL^a DISTRIBUTIONS

<u>St-In</u>	Chi Square	Degrees of Freedom	Probability Level
<u>S-O</u>	7.06	7	.50
<u>S-S</u>	5.97	8	.90
<u>S-M</u>	11.30	5	.05
<u>S-L</u>	15.99	9	.10
<u>M-O</u>	2.63	7	.95
<u>M-S</u>	2.31	5	.90
<u>M-M</u>	2.75	7	.95
<u>M-L</u>	5.94	11	.90
<u>L-O</u>	.97	6	.99
<u>L-S</u>	3.20	6	.90
<u>L-M</u>	4.19	5	.90
<u>L-L</u>	2.69	5	.90

^aThe cells each represent 390 judgments made to the 12 different St-In combinations: 26 subjects times 5 Co times 3 trials.

The assumption that the distributions are normal is evaluated as acceptable despite some ambiguity in the case of S-L and S-M. However, an assumption of homogeneity is untenable. Thus the sign test is used for evaluating cell differences, and the analysis of variance requires transformed data. Table 8 shows the significance level of differences between each cell and every other cell.

Hypothesis II states that the levels of intensity of St will have differential assimilation effects: S-S < M-M; S-S < L-L; M-M < L-L. The obtained mean number of "louder" responses from Table 5 are substituted as follows: $4.23 < 8.27$; $4.23 < 8.27$; $8.27 < 8.27$. Table 8 shows that the null hypothesis may be rejected at the .01 level of confidence for the first and second predictions, but not for the third. Thus the hypothesis is acceptable only with an important qualification.

Hypothesis III states that the greater the In intensity relative to the intensity of the St to which it is assimilated, the less the number of "louder" responses: $\underline{L-S} > \left[\frac{\underline{M-S} \ \underline{L-M}}{2} \right] > \left[\frac{\underline{S-S} \ \underline{M-M} \ \underline{L-L}}{3} \right] > \left[\frac{\underline{S-M} \ \underline{M-L}}{2} \right] > \underline{S-L}$. The obtained values are entered as follows: $10.42 > 10.32 > 6.92 > 5.21 > 3.00$. The mean differences are evaluated by an analysis of variance, single variable of classification. The raw data were first transformed: .5 was added to each observation because of several zero counts, then the square root of each of these data was used. Table 9 shows the results of this analysis of variance.

The null hypothesis is rejected at the .001 level of confidence, thus Hypothesis III is accepted.

TABLE 8

SIGN TESTS OF INTER-CELL^a DIFFERENCES

St-In's Compared		Sign			St-In's Compared		Sign		
		+	-	=			+	-	=
S-O	S-S	7	13	6	S-S	L-L	0	25 ^b	1
S-O	S-M	19 ^b	5	2	S-M	S-L	3	21 ^b	2
S-O	S-L	15	9	2	S-M	M-O	0	26 ^b	0
S-O	M-O	0	26 ^b	0	S-M	M-S	0	26 ^b	0
S-O	M-S	0	26 ^b	0	S-M	M-M	0	26 ^b	0
S-O	M-M	0	26 ^b	0	S-M	M-L	0	26 ^b	0
S-O	M-L	0	25 ^b	1	S-M	L-O	0	26 ^b	0
S-O	L-O	0	26 ^b	0	S-M	L-S	0	26 ^b	0
S-O	L-S	0	26 ^b	0	M-L	L-O	13	9	4
S-O	L-M	0	26 ^b	0	M-L	L-S	7	17	2
S-O	L-L	0	26 ^b	0	M-L	L-M	8	16	2
S-S	S-M	25 ^b	1	0	M-L	L-L	14	5	7
S-S	S-L	17	7	2	L-O	L-S	3	16 ^b	7
S-S	M-O	1	23 ^b	2	L-O	L-M	1	22 ^b	3
S-S	M-S	0	26 ^b	0	L-O	L-L	13	11	2
S-S	M-M	0	25 ^b	1	L-S	L-M	9	10	7
S-S	M-L	0	24 ^b	2	L-S	L-L	19 ^b	5	2

^aThe cells each represent 390 judgments made to the 12 different St-In combinations: 26 subjects times 5 Co times 3 trials.

^b.01 level of probability

TABLE 8—Continued

St-In's Compared		Sign			St-In's Compared		Sign		
		+	-	=			+	-	=
<u>S-S</u>	<u>L-O</u>	1	25 ^b	0	<u>L-M</u>	<u>L-L</u>	20 ^b	4	2
<u>S-S</u>	<u>L-S</u>	1	25 ^b	0	<u>S-M</u>	<u>L-M</u>	0	26 ^b	0
<u>S-S</u>	<u>L-M</u>	0	25 ^b	1	<u>S-M</u>	<u>L-L</u>	0	26 ^b	0
<u>S-L</u>	<u>M-O</u>	1	25 ^b	0	<u>M-O</u>	<u>L-M</u>	4	21 ^b	1
<u>S-L</u>	<u>M-S</u>	0	25 ^b	1	<u>M-O</u>	<u>L-L</u>	10	11	5
<u>S-L</u>	<u>M-M</u>	2	23 ^b	1	<u>M-S</u>	<u>M-M</u>	20 ^b	5	1
<u>S-L</u>	<u>M-L</u>	0	26 ^b	0	<u>M-S</u>	<u>M-L</u>	15	9	2
<u>S-L</u>	<u>L-O</u>	1	25 ^b	0	<u>M-S</u>	<u>L-O</u>	18 ^b	4	4
<u>S-L</u>	<u>L-S</u>	1	25 ^b	0	<u>M-S</u>	<u>L-S</u>	12	12	2
<u>S-L</u>	<u>L-M</u>	1	25 ^b	0	<u>M-S</u>	<u>L-M</u>	11	12	3
<u>S-L</u>	<u>L-L</u>	0	26 ^b	0	<u>M-S</u>	<u>L-L</u>	22 ^b	2	2
<u>M-O</u>	<u>M-S</u>	5	19 ^b	2	<u>M-M</u>	<u>M-L</u>	10	13	3
<u>M-O</u>	<u>M-M</u>	11	10	5	<u>M-M</u>	<u>L-O</u>	7	15	4
<u>M-O</u>	<u>M-L</u>	7	15	4	<u>M-M</u>	<u>L-S</u>	3	18 ^b	5
<u>M-O</u>	<u>L-O</u>	8	10	8	<u>M-M</u>	<u>L-M</u>	5	19 ^b	2
<u>M-O</u>	<u>L-S</u>	4	19 ^b	3	<u>M-M</u>	<u>L-L</u>	13	9	4

^b.01 level of probability

TABLE 9

ANALYSIS OF VARIANCE, SINGLE VARIABLE OF CLASSIFICATION,
FOR CELL^a DIFFERENCES AS A FUNCTION OF STANDARD AND
INTERPOLATED STIMULUS INTENSITY DIFFERENTIAL
HYPOTHESIS III

Sources	Sum of Squares	D.F.	Variance Estimate	F-Ratio
Means	53.03	4	13.26	25.02 ^b
Within	122.00	229	.53	
Total	175.03	233		

^aThe cells each represent 390 judgments made to the 12 different St-In combinations: 26 subjects times 5 Co times 3 trials.

^b.001 level of probability

Hypothesis IV, Lauenstein's assimilation hypothesis, requires more "louder" responses when the St is followed by an empty interval (0 In) than when it is followed by a soft In: $\underline{S-O} > \underline{S-S}$; $\underline{M-O} > \underline{M-S}$; $\underline{L-O} > \underline{L-S}$. These values are entered from Table 5: $3.27 > 4.23$; $8.23 > 10.23$; $8.62 > 10.42$. The difference in the first term is not reliable, and the differences in the second and third terms are significant at the .01 level in the opposite direction from the predictions. Lauenstein's assimilation hypothesis in the case of the empty interval is rejected.

Hypothesis V, Pratt's sinking-trace hypothesis, requires more "louder" responses to each St followed by an empty interval (0 In) than to the St with an In of the same intensity: $\underline{S-O} > \underline{S-S}$; $\underline{M-O} > \underline{M-M}$;

$\underline{L-O} > \underline{L-L}$. The mean numbers of "louder" responses may be entered from Table 5: $3.27 > 4.23$; $8.23 > 8.27$; $8.62 > 8.27$. Table 6 shows that none of these differences is reliable and the hypothesis is rejected.

Hypothesis VI: In the case of the empty interval, the revised assimilation concept holds that the St trace neither "merely sinks" (Pratt) nor becomes assimilated to a zero level of stimulation (Lauenstein), but persists in a relatively stable organization. That is, the trace is as persistent as when followed by an In of the same intensity: $\underline{S-O} = \underline{S-S}$; $\underline{M-O} = \underline{M-M}$; $\underline{L-O} = \underline{L-L}$. The obtained values from Table 5 may be substituted as follows: $3.27 = 4.23$; $8.23 = 8.27$; $8.62 = 8.27$. Table 6 shows that none of these differences are reliable and the hypothesis is accepted.

Thus there is considerable support, both direct and indirect, for the revised assimilation view. The evaluation of inter-test differences indicates that no incompatible effects appear. While Pratt's doubtful refutation of Lauenstein's assimilation hypothesis is confirmed, the sinking-trace hypothesis is also shown to be untenable. The three predictions derived from the revised assimilation hypothesis concerning the "empty interval" are confirmed. The relationships between all five mean In differences are as predicted. The relationships between two of the three St differences are as predicted.

The one unconfirmed St prediction of Hypothesis II ($\underline{M-M} < \underline{L-L}$) is of special interest. Even though the difference was not in the opposite direction from that predicted, it reflects an asymmetry in

the data which may be of importance. That is: the moderate and loud St have little differential effect, either when combined with In of relative value ($\underline{M-S} = \underline{L-M}$; $\underline{M-M} = \underline{L-L}$) or with In of the same intensity ($\underline{M-O} = \underline{L-O}$; $\underline{M-S} = \underline{L-S}$; $\underline{M-M} = \underline{L-M}$, an exception; $\underline{M-L} = \underline{L-L}$).

The most parsimonious explanation is that M (57.5 db.) and L (70.0 db.) are phenomenally more similar than M and S (45.0 db.) under the conditions of this experiment. The results of Discrimination Tests A and B are rather ambiguous regarding this contention. Table 10 shows the number of correct judgments for each St-Co pair in the two tests. In Test A the moderate St-Co are correctly judged more often than the others; but the most marked effect is the higher number of correct judgments made when the Co is louder (e. g., 67.5-70.0 db.), particularly for the loud St-Co. Test B shows an extremely even level of discrimination difficulty, except for one soft St-Co.

If the cell variances of Table 5 are interpreted as measures of difficulty in discrimination, the moderate St are no more similar to the loud St than to the soft St. The subjects' own comments regarding the relative difficulty of judging the various combinations, summarized below, do not support the contention.

Another asymmetry occurs which is of possible theoretical interest. This involves the relationships between S-S, S-M, and S-L; and L-L, L-M and L-S. With S as an St there is an equal In (S-S), a louder In (S-M), and a still louder In (S-L). While both the louder In result in a significant decrease in time-error ($\underline{S-S} > \underline{S-M}$, $\underline{S-S} > \underline{S-L}$),

TABLE 10
 NUMBER OF CORRECT RESPONSES PER TONE COMBINATION OF
 DISCRIMINATION TESTS A AND B

Test A			Test B		
Db.		No. Correct	Db.		No. Correct
<u>St</u>	<u>Co</u>		<u>St</u>	<u>Co</u>	
42.5	40.0	17	45.0	40.0	26
42.5	45.0	14	42.5	47.5	14
47.5	45.0	15	50.0	45.0	26
47.5	50.0	11	52.5	47.5	26
52.5	50.0	14	50.0	55.0	23
52.5	55.0	26	52.5	57.5	22
57.5	55.0	19	60.0	55.0	25
57.5	60.0	23	62.5	57.5	26
62.5	60.0	19	60.0	65.0	23
62.5	65.0	23	62.5	67.5	21
67.5	65.0	8	70.0	65.0	25
67.5	70.0	26	72.5	67.5	26
72.5	70.0	8	70.0	75.0	26
72.5	75.0	25			

the loudest In is significantly less effective than the moderately louder In ($S-L > S-M$). With L as an St there is an equal In ($L-L$), a softer In ($L-M$), and a still softer In ($L-S$). While both the softer In's result in a significant increase in time-error ($L-L < L-M$, $L-L < L-S$), the softer In is no more effective than the moderately soft In ($L-S = L-M$). These asymmetries averaged out in the analysis of variance of Hypothesis III, but they are unexpected according to any current theoretical view. The first may be labelled a "contrast effect," the second a "flattening effect."

These two asymmetries are regarded as by-products of the study in that they have little effect on the hypotheses which the experiment was designed to test. If confirmed, however, they may require further revision of the assimilation view or other theories. Further experimentation is indicated. A design is suggested wherein most of the features of the present study are retained. It might be altered to include additional levels of higher and softer In for each of several St. Since neither fatigue nor practice effects are evident in the current study, a greater number of St and In may be substituted for the repetitions of fewer St and In within several trials.

Individual differences are reflected in an analysis of variance, the sign tests, and the subjects' own comments. The results of a complex analysis of variance are presented below in Table 11. The analysis is pertinent only for subject differences: The rows and columns do not represent St and In contributions to variance.

TABLE 11

COMPLEX ANALYSIS OF VARIANCE FOR SUBJECT DIFFERENCES

Source	Sum of Squares	D.F.	Variance Estimate	F-Ratio
Rows	116.32	2	58.16	7.28 ^a
Columns	3.43	3	1.14	.14
Interaction	47.94	6	7.99	57.07 ^b
Within cells	41.76	300	.14	
Total		311		

^a.05 level of probability

^b.001 level of probability

The within cells variance estimate shows average individual differences to be relatively negligible as a factor. Although these are evaluations of transformed data, an analysis of variance using the original data yielded a very similar F-ratio of interaction variance to within cell variance.

However, in setting up the sign tests of Table 8, the individual differences are striking. The number of "louder" judgments of each St-Co combination were compared with every other combination, subject by subject. There are nine comparisons wherein only one subject differed from the other twenty-five as to direction (plus or minus) of the sign. Six of these reversals are due to only two subjects. One of the same subjects also reversed on the two comparisons wherein only two subjects

differed.

The subjects' comments indicated a variety of approaches, feelings about fatigue and practice effects, and opinions as to which combinations were easier and more difficult. Nine subjects reported that they attempted to use the In as a basis for comparing St and Co at times, two subjects even imagined scales on which they placed each tone. Four subjects actively attempted to ignore the In; three believed they were successful. The comments of seven subjects ("tedious," "monotonous," "harder to concentrate this time") suggested fatigue effects, largely during Trial 3. Two subjects specifically denied fatigue and two others offered to serve as subjects again. Seven subjects felt that the latter trials were easier, suggesting practice effects.

Eight subjects found some of the loud In to border on irritation or unpleasantness (piercing or harsh); one subject used this as a basis for judgment occasionally. Three subjects reported a feeling of relief when a softer tone followed a very loud one.

Opinions on which combinations were easiest and most difficult were quite mixed. The easiest were reported as follows: S-S-3, L-L-3, X-O-3, descending order--2, X-S-2, M-M-1, X-M-1, L-X-1, ascending order--1. (The symbol "X" stands for "any St" if it is the first term in the combination, "any In" if second.) The most difficult were reported as follows: S-L-5, X-L-4, X-O-3, L-M-3, S-S-2, M-L-2, S-M-1, M-S-1, L-S-1, L-L-1. This suggests that, as a group, the

difficulty of discrimination was fairly evenly distributed.

Thus, while individual differences are quite apparent, they seem to average out in the group results.

CHAPTER IV

SUMMARY AND CONCLUSION

Twenty-six subjects made judgments of the relative loudness of 60 standard stimulus-interpolated stimulus-comparison stimulus (3 St x 4 In x 5 Co) tone combinations, which were replicated in three successive trials under the Method of Constant Stimuli-180 judgments per subject.

The experiment was designed to evaluate differences in time-error in the following areas: inter-trial differences; the effect of varying the intensity level of St, with In controlled; and the effects of varying In, with St controlled. Predictions derived from six hypotheses were tested. These concern Lauenstein's assimilation hypothesis, Pratt's sinking-trace effect, and a revised assimilation concept.

Hypothesis I was that if significant inter-trial differences occurred they would be in the direction of progressive assimilation effects, as defined in Hypotheses II, III, and VI. The obtained inter-trial differences were evaluated as non-significant, and the following interpretations were made:

1. No successive stages in the emergence of assimilation effects are identified.

2. The experimental procedure was appropriate for precluding significant practice and fatigue effects. Thus some of the design features might be considered in further experimentation.
3. No extraneous inter-trial effects intrude to detract from the generality of assimilation phenomena.

Hypothesis II concerned the differential effects of varying St intensity, In controlled. According to the revised assimilation view, a soft St would decrease the gradient system level, leading to overestimation of the Co; but a loud St would have the opposite effect. The predicted time-error differences were obtained between soft and moderate and soft and loud, but not moderate and loud St. The contention was entertained that the latter unconfirmed St prediction was due to the moderate and loud stimuli being more similar than the moderate and soft ones. However, evidence from the discrimination tests, the St-Co variances, and the subjects' reports did not support the contention.

Hypothesis III concerns the effects of varying In intensity, exclusive of zero In or the empty interval, with St controlled. It was predicted from the revised assimilation view that the greater the In intensity in relation to the intensity of the St to which it is assimilated, the greater the underestimation of Co. The prediction was confirmed at five levels, ranging from In with St two steps lower to two steps higher.

Hypotheses IV to VI concern the zero In or empty interval. Each hypothesis was tested at all three levels of St intensity—soft,

moderate and loud.

Hypothesis IV is Lauenstein's assimilation hypothesis. If the St is assimilated to a zero In the Co would be overestimated more than if the St were followed by a soft In. The hypothesis is rejected at all three St levels.

Hypothesis V is Pratt's sinking-trace hypothesis. To be confirmed, the Co must be overestimated more when an St is followed by an empty interval than when followed by an In of equal intensity. The hypothesis was rejected at all St levels.

Hypothesis VI, the revised assimilation hypothesis, holds that the gradient established at the time of St persists as stably in the absence of an In excitation as if followed by an In of equal intensity. The predictions were confirmed at all three St levels.

The revised assimilation conception holds that the phenomenal experience of comparison is the psychological parallel of an excitation being assimilated to the traces of past excitations. The traces are organized in relatively persistent subsystems which interact with one another and the whole gradient system. The current excitation—whether St, In, or Co—is assimilated to a subsystem of a similar character, e. g., the same sense modality and attribute. Thus tonal excitations varying in intensity are assimilated to a subsystem of tonal intensity traces. However, tonal intensity may be affected by pitch and even illumination through subsystem interaction, depending on their cohesiveness and insulation. The general Gestalt principles

of figure-ground system formation—contrast, proximity, symmetry, articulation, etc.—are assumed to function. While the viewpoint is associated with an electro-chemical rather than a structural, theory of cortical action, the view need not be dependent on any such theory.

The results summarized above lend support to the revised assimilation view. It is conceivable that some of the predictions which are confirmed could have been made from an empirical "set" theoretical model. However, the fact that In differences in time-error are a function of the relative St-In intensity differential gives the results a Gestalt character.

In addition, Pratt's sinking-trace concept is rejected. Pratt's conclusion that the trace "merely sinks" in the empty interval probably describes his results because of the lack of a control In, other questions of experimental design aside. The present study indicates that the St trace sinks no more in the empty interval than with an In of equal intensity. This conclusion indirectly applies to Woodrow's "set" theory. Woodrow assumed that the "...set tends in all cases to sink toward a lower level..." It is the present view that sinking-trace or set is not a universal phenomenon, but that data suggesting such an effect are obtained when the trace subsystem is poorly organized or interacts with a subsystem of lesser intensity. Thus the present study might be considered to involve only well-organized trace configurations.

Individual differences were cited, including the subjects'

impressions regarding approach, fatigue and practice effects, and the relative difficulty of tone combinations. However, subject differences did not seriously affect the reliability of the group results.

LIST OF REFERENCES

1. Helson, H. Adaptation-level as a frame of reference for prediction of psychophysical data. Amer. J. Psychol., 1947, 60, 1-29.
2. Holzman, P. S. and Klein, G. S. Cognitive system-principles of leveling and sharpening; individual differences in assimilation effects in visual time-error. J. Psychol., 1954, 37, 105-122.
3. Koehler, W. Zur Theorie des Sukzessivvergleichs und der Zeitfehler. Psychol. Forsch., 1923, 4, 115-175.
4. Lauenstein, O. Ansatz zu einer physiologischen Theorie des Vergleichs und der Zeitfehler. Psychol. Forsch., 1933, 17, 130-174.
5. Needham, J. G. The time-error in comparison-judgments. Psychol. Bull., 1934, 31, 229-243.
6. Needham, J. G. The time-error as a function of continued experimentation. Amer. J. Psychol., 1934, 46, 558-567.
7. Needham, J. G. Interpolation effects with different time intervals. J. exp. Psychol., 1935, 18, 767-773.
8. Postman, L. The time-error in auditory perception. Amer. J. Psychol., 1946, 59, 193-219.
9. Pratt, C. C. The time-error in psychophysical judgments. Amer. J. Psychol., 1933, 45, 292-297.
10. Pratt, C. C. Time-error in the method of single stimuli. J. exp. Psychol., 1933, 16, 798-814.
11. Weinstein, S. Time-error in weight judgments after brain injury. J. comp. physiol. Psychol., 1955, 48, 203-207.
12. Woodrow, H. Weight discrimination with a varying standard. Amer. J. Psychol., 1933, 45, 391-416.
13. Woodrow, H. The temporal indifference interval determined by the method of mean error. J. exp. Psychol., 1934, 17, 167-188.
14. Woodworth, R. S., and Schlosberg, H. Experimental psychology. (Rev. ed.) New York: Henry Holt, 1954.

VITA

John A. Bowland was born in South Bend, Indiana, in 1928. After service in the U. S. Army, he attended the University of Chicago and Indiana University, where the B. A. degree was conferred in 1951. Following the M. A. degree at the University of Florida in 1954, further graduate work there was combined with two years of training in the University of Florida-Veterans Administration clinical psychology training program. For the past year he has been a staff psychologist at the Diagnostic Center of the Dade County Public Schools in Miami, Florida.

This dissertation was prepared under the direction of the chairman of the candidate's supervisory committee and has been approved by all members of the committee. It was submitted to the Dean of the College of Arts and Sciences and to the Graduate Council and was approved as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

June 9, 1958

B. F. Cyers
Dean, College of Arts and Sciences

Dean, Graduate School

SUPERVISORY COMMITTEE:

J. C. Dixon
Chairman

G. R. Brettell

C. W. Hunkley

R. H. Waters

E. F. Rame